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ULTRASONIC SPOT WELDING ASSEMBLY AND METHOD

This invention relates to an ultrasonic welding apparatus. More particularly, this application relates to a spot welding tip for an ultrasonic welding apparatus.

5 Ultrasonic welding has been used for bonding in a number of materials. Most commonly, ultrasonic bonding is utilized in thermoplastic materials. Recently, it has been discovered that ultrasonic spot welding could be accomplished. See, for example,
10 the November-December 1980 issue of Plastics Design Forum, page 86. This publication describes techniques of ultrasonic spot welding as well as the advantages in producing a clean appearance on the surface opposite the weld. This article describes a process
15 for welding two thermoplastic sheets together wherein a standard welding tip penetrates one sheet and extends some way through the second. The article further addresses the possibility of inverse spot welding, that is, fitting the welding tip to a
20 mounting fixture or anvil, and utilizing a flat-faced horn to provide ultrasonic energy.

The use of ultrasonic spot welding is further described in an article entitled "Ultrasonic Assembly," by R.A. Clarke published in the 1980-81 Modern Plastics
25 Encyclopedia, page 447-450. In this article, Clarke discloses the general advantages of an annular ring design in the horn or tip for ultrasonic spot welding.

None of the above-referenced ultrasonic welding
30 tip configurations or methods provide a suitable means for permitting the free flow of melted thermoplastic material away from the weld joint and tip therein during the welding process. The accumulation of

melted material in this region may interfere with the continued melting of the unmelted material at the weld joint (it absorbs ultrasonic energy) and so lends itself to thermal degradation which
5 may result in a weld joint of insufficient strength. Furthermore, this melted material may cause overheating of the weld tip configuration, which can damage the welds and surrounding sheet material.

Viewed from one aspect the present invention
10 provides a method of ultrasonically spot welding together a plurality of sheets of thermoplastic material along a weld line, in which a plurality of welding tips mounted on a support are inserted into the sheets along said line so that each tip at least partially
15 penetrates each sheet, ultrasonic energy is supplied to the sheets adjacent to the welding tips so as to weld the sheets together, and molten material is permitted to flow away from the sheets into reservoir portions adjacent the welding tips.

20 Viewed from a second aspect the present invention provides apparatus for ultrasonically spot welding together a plurality of sheets of thermoplastic material along a weld line by a method as claimed in claim 1, comprising a plurality of welding tips mounted
25 on a support, means for causing insertion of the welding tips into the sheets along said line, means for controlling the extent of such insertion such that in use the tips will at least partially penetrate each sheet whilst the support is spaced from the
30 sheets so that reservoir portions are defined between the support and the sheets, and means for supplying ultrasonic energy to the sheets adjacent to the welding tips so as to weld the sheets together, the reservoir portions serving in use to receive molten material
35 which flows away from the sheets adjacent the welding tips.

Viewed from a third aspect the present invention may be seen as providing apparatus for ultrasonically

spot welding together a plurality of sheets of thermoplastic material along a weld line, by a method as claimed in claim 1, comprising a plurality of welding tips mounted on a support, a plurality of recessed portions
5 in the support adjacent the welding tips but spaced therefrom, means for causing insertion of the welding tips into the sheets so that in use the tips will at least partially penetrate each sheet, and means for supplying ultrasonic energy to the sheets adjacent
10 to the welding tips so as to weld the sheets together, the recessed portions in the support serving in use as reservoir portions to receive molten material which flows away from the sheets adjacent the welding tips.

15 Viewed from a further aspect the present invention provides a system for spot welding a plurality of sheets of thermoplastic material together comprising:

(a) a plurality of welding tips adjacent
20 to an obverse face of juxtaposed sheets of said thermo-plastic material, each of said welding tips extending from an anvil and having a base attached to said anvil and an apex spaced from said anvil at a predetermined height above said anvil, said
25 plurality of welding tips extending along a weld line to be formed in said juxtaposed sheets;

(b) means for inserting said welding tips into an obverse face of said juxtaposed sheets a sufficient distance so that each welding tip
30 at least partially penetrates each sheet of material being welded, said distance being less than the height of said apex of said each welding tip above the anvil from which said each welding tip extends, to thereby provide a reservoir space between said
35 anvil and the obverse face of said sheet material; and

(c) means for applying ultrasonic energy to said thermoplastic sheet material adjacent to

said welding tips whereby melted material may freely flow into said reservoir space.

Viewed from yet another aspect the present invention preferably provides a method for ultrasonically spot welding together a plurality of sheets of thermoplastic material along a weld line, comprising the steps of positioning a source of ultrasonic energy adjacent to a first outer surface of the plurality of sheets, positioning a support carrying a plurality of welding tips adjacent to a second outer surface of the plurality of sheets opposite said first outer surface and the source of ultrasonic energy, inserting the welding tips into the sheets along said line such that they at least partially penetrate each sheet, there being regions of the support adjacent the bases of the welding tips which are spaced from said second outer surface of the plurality of sheets, and supplying ultrasonic energy from said source so as to weld the sheets together.

Viewed from one further aspect in preferred embodiments the invention provides a welding tip assembly for applying ultrasonic energy to a plurality of juxtaposed sheets of thermoplastic material to spot weld the sheets together comprising:

an anvil for supporting at least one frusto-conical welding tip, the base of said welding tip being supported by a major surface of said anvil and having a maximum base dimension B parallel to said major surface, the apex of said cone-shaped tip being disposed at a height A above said major surface, the ratio of A/B being approximately 0.76.

Viewed from still another aspect in preferred embodiments the invention provides A welding tip assembly for applying ultrasonic energy to a plurality of juxtaposed sheets of thermoplastic material to spot weld the sheets together comprising:

an anvil for supporting at least one cone-shaped welding tip, the base of said cone-shaped welding tip being supported on a major surface of said anvil and having a maximum base dimension
5 B parallel to said major surface, the apex of said cone-shaped tip being disposed at a height A above said major surface, the ration of A/B being approximately 1.2.

Thus in preferred embodiments the present
10 invention discloses a welding tip which includes a plurality of conical projections interspersed with a plurality of reservoir portions. The conical projections are placed in contact with the material to be welded and ultrasonic energy is applied to
15 the material. The ultrasonic energy is concentrated and the melt is dispersed by the conical projections and heats the sheet material adjacent to these projections to thereby soften the material. The softened material is displaced by the conical projections
20 and may be gathered in reservoir portions of the tip which are provided for accumulation of any displaced material. The material continues to be softened and displaced until the conical projections are substantially fully inserted into the sheet
25 material. The conical projections in the preferred embodiments are right circular conical, right circular frusto-conical or pyramid in shape or are configured so as to allow self-release of the sheet material therefrom. Preferably the reservoirs are constructed
30 with a volume significantly greater than the volume of the conical projection in order to allow for expansion in any displaced material.

In one embodiment a plurality of weld tip configurations are provided on a common support and the welding
35 tips on the anvil of each are selectively removable to provide different weld tip configurations depending on the characteristics of the materials being welded.

In one embodiment the weld tip support is disposed along a weld line and the ultrasonic energy is applied by a welding horn extending along the weld line. The welding horn tends to generate
5 weaker ultrasonic energy in peripheral regions, such as those adjacent the distal ends of the welding horn. Accordingly, to compensate for the weaker ultrasonic energy in these regions, in a preferred embodiment the tips may be made slightly longer
10 than in intermediate regions or the tips may be disposed in more shallow counterbores in the associated anvils to engage a greater diameter of the tip therefore displacing more material. An alternative approach would be to employ a welding horn of greater
15 length than the weld line to avoid edge effects.

In a first preferred embodiment of the present invention, the welding tips are right circular cones with heights A above the anvil and base diameters B at the anvil. An ideal ratio of A/B is 1.2 in
20 a first preferred embodiment and 0.76 in a second preferred embodiment. With these ratios, the tips are self-releasing and also penetrate sheet material with a minimum of energy.

The present invention is intended to provide
25 an improved ultrasonic welding apparatus and method, particularly to produce improved ultrasonic spot welds in sheet thermoplastic material.

Preferably such welds can be provided along a relatively lengthy weld line and can be produced
30 with a welding tip configuration which is self-releasing from the sheet material upon completion of the weld due to its full tapered symmetry.

A preferred embodiment provides a welding tip of a sufficient height to provide a natural
35 reservoir between the support base of the welding tip configuration and the weld tips per se.

A further embodiment provides removable weld tips and means for changing the number of welding

tips and/or the size of the tips used in order to facilitate optimum weld strength along the line of the weld with varying materials and varying thicknesses to be welded.

5 Another embodiment provides optimally dimensioned and shaped weld tips to create optimum strength weld joints and smooth self-release of the tips from the melted sheet material.

10 Still another embodiment provides a welding tip which may be used for inverse spot welding in thermoplastic material and which may be removed from contact with the sheet material by displacement only in a direction parallel to the line along which the spot welds are produced.

15 A number of specific examples embodying some of the above features will now be described by way of example only with reference to the accompanying drawings wherein:

20 Figure 1 is a perspective of a portion of a welding tip according to an embodiment of the present invention;

 Figure 2 is a schematic perspective of the use of the welding tip of Fig. 1 in welding sheet material in an inverse spot welding process;

25 Figure 3 is a perspective of a portion of the welding tip of Fig. 1 illustrating the provision of cooling passages therein; and

 Figure 4 is a perspective of a portion of a welding tip according to an embodiment of the present invention in which the semi-spherical reservoirs are replaced by troughs disposed adjacent the cylindrical projections and parallel to the weld line.

30 Figure 5 is a perspective of a welding tip configuration of a first preferred embodiment of the present invention;

 Figure 6 is an enlarged frontal view of a single welding tip of the first preferred embodiment of the present invention;

Figure 7 is a schematic side view of the operation of a single welding tip of the type illustrated in Figure 6 for welding sheet material in an inverse spot welding process utilizing a positive stop

5 for the weld horn;

Figure 8 is a top planar view of an anvil support bar illustrating a plurality of weld tip groups extending along a weld line; and

Figure 9 is a second preferred embodiment
10 of a weld tip according to the present invention for welding sheet material in an inverse spot welding process which permits the elimination of the positive stop of Figure 7.

Referring to figure 1, the welding tip of
15 an embodiment of the present invention (generally indicated as 10) includes a plurality of conical projections 12 alternately interspersed with a plurality of reservoirs 14 along a tip base 16. The conical projections 12 serve to concentrate
20 ultrasonic energy where they contact the sheet material at their respective apices 18. While the conical projections may be formed in any shape suitable for concentrating the ultrasonic energy and facilitating self-release which will be described
25 hereinbelow, figure 1 illustrates one form of cone. It should be noted, that the term cone is intended to encompass its broadened meaning and is not intended to limit the present application to the right circular cone which is merely one embodiment of cone utilizable
30 in the welding tip of the present invention.

In a welding tip such as that of a preferred embodiment as illustrated in figure 1, the distance between cone apex and base may be configured to equal approximately one and one-half times the
35 thickness of the sheet material to be welded. Further, in this embodiment the cone base is constructed with a width of approximately twice the cone's height or about three times the thickness of the sheet material to be bonded.

Figure 2 illustrates the use of the tip 10 of figure 1 in an inverse ultrasonic spot welding process. To facilitate inverse ultrasonic spot welding, the welding tip 10 is securely fastened to an anvil or mounting bar 20 which is positioned on one side of two sheets of material to be welded 30, 40. Figure 2 further illustrates the placement of an ultrasonic transducer or horn 50 on the other side of the sheets of material to be bonded by spot welding according to the teachings of the present invention.

The spot welder schematically illustrated in figure 2 functions as follows. The material to be bonded is supported by a support 60 with the first and second sheets 30, 40 juxtaposed along the desired lines to be welded. The tip 10 of the present embodiment is presented into contact with one side of the juxtaposed first and second sheets of material 30, 40 by movement of the anvil 20 upon which it is disposed. Simultaneously, the ultrasonic transducer or horn 50 is moved in a line perpendicular to the plane of the respective sheets of materials in order to engage the other side of the sheets. Ultrasonic energy is applied to the sheets of material to be bonded via the ultrasonic horn 50. As the conical projections 12 of the welding tip 10 contact the sheet material at alternating spots therealong, the ultrasonic energy is concentrated at these spots. The sheet material is thereby softened and displaced by contact with the conical projections 12. The sheet material which is softened is accumulated in reservoirs 14 to remove the material from the area of ultrasonic energy concentration to avoid overheating of the softened material and to concentrate the ultrasonic energy on unsoftened material.

When the spot welds have been completed to their desired depth with the conical projections

fully inserted into the sheet material, the ultrasonic energy is withdrawn. Cooling of the sheet thermoplastic causes shrinkage thereof. The configuration of the conical projections 12 is such that the welding tip self-releases from the sheet material. Thus, the configuration of the welding tip of figure 1 facilitates self-release of the tip from the sheet material after welding and produces improved welds by providing reservoirs for accumulating the softened sheet material juxtaposed to the conical projections 12.

While the figure 2 embodiment of the present invention illustrates the technique known as inverse spot welding, it is possible to utilize the welding tip of the present invention in normal spot welding by affixing the tip to the ultrasonic horn 50.

The reservoirs 14 of the figure 1 welding tip are semi-spherical in shape and are typically sized to accumulate about 1.5 times the volume displaced by an associated conical projection. The volume of each reservoir is typically at least 1 and 1/3 times the volume of an associated conical projection.

When the system of the present embodiment is utilized in automated production, residual heat buildup within the welding tip can be troublesome. Without adequate precautionary measures, the temperature of the welding tip can become sufficient to cause the sheet material to melt to the welding tip. Referring to figure 3, where like numerals designate like parts with figure 1, cooling passages may be provided within the welding tip 10 in order to control the temperature thereof. The temperature may then be controlled by controlling the flow rate of the coolant or by other means in order to maintain the welding tip to the desired temperature. With polyethylene, it is desirable to maintain the temperature at about 32° celsius (90° Fahrenheit).

When the welding tip reaches 54° to 60° Celsius (130° to 140° Fahrenheit), the polyethylene begins to stick to the tip. The weld tip 10 of the present invention may be either made integral with the
5 anvil 20 or may be made replaceably fixable thereto.

In the specific application for which the system of the present embodiment is utilized, it is necessary to move the anvil 20 and weld tip 10 into place by moving the anvil in a direction
10 parallel to the weld line produced. No significant movement perpendicular to the plane of the sheet materials is therefore permitted in this embodiment. Therefore, it is desirable to configure the weld tip so as to easily slide away from the completed
15 weld along a direction parallel to the weld line.

In figure 4, where like elements are also designated by like numerals, a modified weld tip is illustrated wherein the semispherical reservoirs of figure 1 are replaced by a pair of peripheral
20 troughs 22, 24 arranged on either side of the alternately arranged conical projections 12. These troughs 22, 24 are fed by a plurality of feeder trough reservoir portions 26 which direct the molten sheet material into troughs 22, 24 for collection. Upon
25 completion of the weld, the weld tip of figure 4 may be more easily removed from juxtaposition with the sheet material in a direction parallel to the mold line as there is no significant accumulation of material between the interspersed conical projections
30 12 in the area where the reservoirs 14 of the figure 1 embodiment would otherwise accumulate material. Therefore, the lateral movement of the weld tip may be more easily facilitated.

Referring to figure 5, a single group of
35 welding tips (generally indicated as 10) includes a plurality of staggered conical projections 82 removably mounted within the anvil body 90 or support plate 90. A plurality of optional drill-formed

well reservoirs R may be provided between projections 82. A plurality of such welding groups would typically be disposed along a welding line. The conical projections 82 serve to concentrate ultrasonic energy and disperse the melt where they contact the sheet material at their respective apices 88. While the conical projections 82 may be formed in any shape suitable for concentrating the ultrasonic energy and facilitating self-release, which will be described hereinbelow, figure 5 illustrates one form of cone. It should be noted that the term "cone" is intended to encompass its broadened meaning and is not intended to limit present application to a right-circular cone which is merely one embodiment of cone usable in the welding tips of the present invention. For example, a pyramid also falls within the generic definition of a cone.

Figure 6 is an enlarged diagrammatic illustration of a single welding tip of a first preferred embodiment of the present invention. Welding tip 11 is a single unit comprising a shank 83, a base portion 84 having a diameter B and a conical projection 82 of a height A extending upwardly from this base portion. In a welding tip such as that illustrated in figure 6, the distance of height A between cone apex 88 and its junction with base portion 84 should be configured to equal approximately three times the thickness of a single sheet of material of two equal thickness sheets to be welded together. Further, the tip is preferably constructed such that the ratio of height A to width B of base portion 84 equals approximately 1.2.

Figure 7 is a diagrammatic side elevational view illustrating the operation of a single welding tip 11 of the present embodiment for welding sheet material in an inverse spot welding process. To facilitate inverse ultrasonic spot welding, the welding tip 11 is fastened to a stationary anvil

or mounting bar 90, which is positioned on one side of two substantially equal thickness sheets of material 100, 110 to be welded together. Figure 7 further illustrates the placement of a movable
5 horn 120 on the opposite side of the sheets of material to be bonded by spot welding according to the teachings of the present invention. A positive stop 86A mounted on the horn 120 is operatively associated with a stationary stop 86B to limit
10 the downward stroke of the horn. As horn 120 is lowered, it pushes sheets 100 and 110 against welding tip 81, causing cone 82 to pierce sheet 110 and penetrate sheet 100 by approximately half its thickness. The degree of penetration is, of course, controlled
15 by the positions of stops 86A, 86B. Therefore, approximately 1.5 sheet thicknesses A_1 are penetrated by cone 82. Cone 82 has a height of approximately $3A_1$ (3 times the sheet thickness). Accordingly, a free reservoir space 89 of a thickness B_1 results
20 between sheet 110 and anvil 90.

Ultrasonic energy is applied to the sheets of material to be bonded via the ultrasonic horn 120. As the plurality of conical projections 82 of the ultrasonic welding tips 81 penetrate the
25 sheet material along the weld line, the ultrasonic energy is concentrated and the melt is dispersed at these spots. The sheet material is thereby softened, forming melt pools 92 between the sheets. Molten material, as at 94 is also accumulated
30 in the free space 89 between anvil 90 and sheet 110. As stated hereinbefore, space 89 is created by stops 86A and 86B which allows the cones 82 to be inserted only through sheet 110 and approximately half the sheet thickness into sheet 100. The back
35 flow of molten material produced by the ultrasonic welding action literally hangs at 94 from the sheets 100, 110 above the anvil 90. The free flow of the molten sheet material effectively removes a

substantial portion of molten material from the region of the ultrasonic energy concentration and avoids overheating of the molten material so removed. Thus, ultrasonic energy can be better concentrated
5 on unsoftened material to continue the welding process.

When the spot welds have been completed to their desired depth (1.5 times the thickness of the bottom sheet 110, the positive stops 86A, 86B
10 controlling this distance), the application of ultrasonic energy is terminated. Cooling of the sheet thermoplastic causes shrinkage thereof. The configuration of the conical projections 82 is such that the cone 82 of welding tip 81 self-
15 releases from the sheet material.

Thus, the configuration of the welding tip of figures 5, 6 and 7 facilitates self-release of the tip from the sheet material after welding and produces improved welds by providing a natural
20 reservoir space for accumulating a substantial portion of the softened or molten sheet material flowing from positions juxtaposed to the conical projections 82.

Further, the pointed and elongated tip portion
25 82 with a height-to-base ratio of approximately 1.2, as illustrated in figure 6, allows for an enhanced piercing action through the sheet material which requires less load on the power supply during the welding process and still provides adequate
30 weld strength.

Still further, the taper on the conical projection 82 is about 45°, resulting in less displaced melted sheet material and provides a cosmetically more acceptable weld.

35 While the figure 7 embodiment of the present invention illustrates the technique known as inverse spot welding, it is also possible to utilize the tip of the present invention in normal spot welding by affixing the tip to the ultrasonic horn 120.

The outer zones of an ultrasonic welding horn 120, typically generate lower amplitude ultrasonic energy and therefore produce weaker welds at the outer peripheral zones of the horn. In accordance with the embodiment of the present invention as illustrated in figure 8, weld tip groups W_1 and W_7 in the peripheral outer zones of an anvil support bar AB have a counterbore depth (85, figure 7) for placement of the base of the removably mounted tips which is about 0.0254 centimetres (0.010 inches) shallower than the counterbores of the remaining tip groups W_2 to W_6 on the anvil support bar along the weld line. Thus, cones 82 in tip groups W_1 and W_7 penetrate further into sheets 100, 110. This compensates for the inherent feature of lower power output at outer zones of the ultrasonic horn 120.

The shanks 83 and bases 84 of welding tips 11 are removably mounted in the anvil body 90 in counterbore sockets, as illustrated in figure 7, for ease of maintenance and replacement. More importantly, the number of tips in each grouping and the size of the tips in each grouping on the anvil may be easily changed to vary the optimum weld strength along a weld line. This permits the welding of a wider variety of polymer materials and/or a wider range of varying sheet thicknesses even though generally more melt pools per grouping will result in a higher tensile strength per group.

In the preferred embodiment, the welding tips of the present invention are utilized to spot weld high-density polyethylene sheets. However, any suitable material may be welded utilizing the welding apparatus of the present invention.

Similarly, the welding horn could be made of any suitable material as can the welding tips of the present invention. In the preferred embodiments, the welding tips 81 are manufactured of aluminum

and are then hard-coat anodized for better abrasion resistance. The tip is then treated with polytetrafluoroethylene, known under the trademark "TEFLON", to prevent surface sticking. Further, the welding tips 81 can also be manufactured from other materials such as carbonized steel with proper heat treatment.

Previously, the use of this type of system in automated production resulted in residual heat buildup within the welding tip. Cooling passages had to be provided within the anvils in order to control the temperature of the welding tips. In the present embodiments proper tip geometry and number of tips per group along the weld line reduce residual heat buildup as disclosed hereinabove. Still further, since the anvil never contacts the molten material or sheets being welded, less heat is applied to the anvil.

Figure 9 is an enlarged diagrammatic illustration of a single welding tip of a second preferred embodiment of the present invention as utilized in an inverse welding process. Welding tip 81 is a single unit comprising a shank 83, a base portion 84 having a diameter B and a frusto-conical projection 82 of a height A extending upward from this base portion. It should be understood that the welding tip of figure 9 may be substituted for the welding tip of figure 6 in the illustrations of figures 5 and 8. In a welding tip such as that illustrated in figure 9, the distance of height A between the distal end cone and its junction with base portion 84 should be configured to equal approximately one and one-half times the thickness of a single sheet of material of two equal thickness sheets to be welded together. Further, the tip is preferably constructed such that the ratio of height A to width B of base portion 84 equals approximately 0.76.

Figure 9 also illustrates the operation of the second preferred embodiment of a single welding tip 81 of figure 9 for welding sheet material in an inverse spot welding process. To facilitate
5 inverse ultrasonic spot welding, the welding tip 81 is fastened to a stationary anvil or mounting bar 90, which is positioned on one side of two substantially equal-thickness sheets of material 100, 110 to be welded together. Figure 9 further
10 illustrates the placement of a movable horn 120 on the opposite side of the sheets of material to be bonded by spot welding according to the teachings of the present invention.

With the welding tip of figure 9, the positive
15 stop 86A of figure 7 may be eliminated or, if desired, it may be retained. As horn 120 is lowered, it pushes sheets 100 and 110 against weld tip 81, causing frusto-conical tip 82 to pierce sheets 110 and penetrate sheet 100 by more than half its
20 thickness. The degree of penetration is, of course, controlled by the height of the frusto-conical tip 82 above the shoulder 84S of base 84 of the welding tip 81. Therefore, more than 1.5 sheet thicknesses A_1 are penetrated by frusto-conical
25 tip 82. The height of frusto-conical tip 82 plus the extension of base 84 above the top of anvil body 20 is approximately $3.5A_1$ (3.5 times the sheet thickness). Accordingly, a free reservoir space 89 of a thickness B_1 results between sheet 110
30 and anvil 90.

Ultrasonic energy is applied to the sheets of material to be bonded via the ultrasonic horn 120. As the plurality of conical projections 82 of the ultrasonic welding tips 82 penetrate the
35 sheet material along the weld line, the ultrasonic energy is concentrated at these spots. The sheet material is thereby softened, forming melt pools 92 between the sheets. Molten material, as at

94, is also accumulated in the free space 89 between anvil 90 and sheet 110. As stated hereinbefore, space 89 is created by the extension of base 84 and shoulder 84S above the top of anvil 90, which
5 allows the frusto-conical tips 82 to be inserted to the controlled depth of the tips' height into sheets 100, 110. As in the figure 7 embodiment, the back flow of molten material produced by the ultrasonic welding action literally hangs at 94
10 from the sheets 100, 110 above the anvil 90. The free flow of the molten sheet material effectively removes a substantial portion of molten material from the region of the ultrasonic energy concentration and avoids overheating of the molten material so
15 removed. Thus, ultrasonic energy can be better concentrated on unsoftened material to continue the welding process.

When the spot welds have been completed to their desired depth (the shoulder 84S of base 84
20 controlling this distance), the application of ultrasonic energy is terminated. Cooling of the sheet thermoplastic causes shrinkage thereof. The configuration of the frusto-conical tips 82 is such that the tip 82 of welding tip 11 self-
25 releases from the sheet material.

Further, the shoulder 84S of base 84 as it extends a distance B_1 above the top of the anvil body 90 also disperses evenly and radially the molten material between the juxtaposed sheets,
30 producing a uniform, and therefore stronger, weld due to the pressure exerted on the sheets 100 and 100 by the horn 120 against the shoulder 84S of base 84.

Still further, the taper on the frusto-conical
35 tip 82 has an included angle of approximately 45° , resulting in less displaced melted sheet material and provides a cosmetically more acceptable weld.

The present invention can be used to spot weld sheet thermoplastic material.

It should become apparent to one of ordinary skill in the art that various changes and modifications
5 may be made in the devices above described which are within the scope of the invention.



MO 148-827

CLAIMS

1. A method of ultrasonically spot welding together a plurality of sheets of thermoplastic material along a weld line, in which a plurality of welding tips mounted on a support are inserted into the sheets along said line so that each tip at least partially penetrates each sheet, ultrasonic energy is supplied to the sheets adjacent to the welding tips so as to weld the sheets together, and molten material is permitted to flow away from the sheets into reservoir portions adjacent the welding tips.
2. A method as claimed in claim 1 wherein the welding tips are inserted into the sheets by a distance such that the support is spaced from the sheets and said reservoir portions are defined between the support and the sheets.
3. A method as claimed in claim 1 wherein recessed portions are provided in the support adjacent the welding tips so as to define said reservoir portions.
4. A method as claimed in claim 3 wherein the recessed portions are adjacent to, but spaced from, the welding tips.
5. A method as claimed in any of claims 1 to 4 wherein the ultrasonic energy is supplied from an ultrasonic horn extending along said weld line.
6. A method as claimed in claim 5 wherein the ultrasonic horn is positioned on the side of the sheets remote from the welding tips.



7. A method as claimed in claim 5 or 6 wherein the welding tips are arranged in a line, with the tips adjacent the ends of the line extending further from the support than the tips in an intermediate part of the line.

8. Apparatus for ultrasonically spot welding together a plurality of sheets of thermoplastic material along a weld line by a method as claimed in claim 1, comprising a plurality of welding tips mounted on a support, means for causing insertion of the welding tips into the sheets along said line, means for controlling the extent of such insertion such that in use the tips will at least partially penetrate each sheet whilst the support is spaced from the sheets so that reservoir portions are defined between the support and the sheets, and means for supplying ultrasonic energy to the sheets adjacent to the welding tips so as to weld the sheets together, the reservoir portions serving in use to receive molten material which flows away from the sheets adjacent the welding tips.

9. Apparatus as claimed in claim 8 wherein each welding tip is associated with a shoulder serving as a stop to limit the extent of insertion of the tip into the sheets of material.

10. Apparatus for ultrasonically spot welding together a plurality of sheets of thermoplastic material along a weld line, by a method as claimed in claim 1, comprising a plurality of welding tips mounted on a support, a plurality of recessed portions in the support adjacent the welding tips but spaced therefrom, means for causing insertion of the welding tips into the sheets so that in use the tips will at least partially penetrate each sheet, and means for supplying ultrasonic energy to the sheets adjacent



to the welding tips so as to weld the sheets together, the recessed portions in the support serving in use as reservoir portions to receive molten material which flows away from the sheets adjacent the welding tips.

11. Apparatus as claimed in claim 10 wherein the total volume of the recessed portions is one and one third the total volume of the welding tips.

12. Apparatus as claimed in claim 10 or 11 wherein a recessed portion is associated with each welding tip.

13. Apparatus as claimed in claim 12 including a plurality of recessed portions alternately disposed with the welding tips along the support.

14. Apparatus as claimed in any of claims 10 to 13 wherein the recessed portions are integrally formed with the support.

15. Apparatus as claimed in any of claims 10 to 14 wherein the recessed portions are semi-spherical in shape.

16. Apparatus as claimed in any of claims 10 to 15 wherein the recessed portions include a trough parallel to the weld line and portions for channeling molten material into the trough.

17. Apparatus as claimed in claim 16 wherein a trough is provided on each side of the weld line.

18. Apparatus as claimed in any of claims 8 to 17 herein the welding tips are integrally formed with the support.



19. Apparatus as claimed in any of claims 8 to 17 wherein the welding tips are selectively removable from the support.

20. Apparatus as claimed in any of claims 8 to 19 wherein the welding tips are staggered in two parallel lines along the welding line.

21. Apparatus as claimed in any of claims 8 to 20 wherein the welding tips are clustered in groups.

22. Apparatus as claimed in any of claims 8 to 21 wherein the welding tips are hard coat anodized.

23. Apparatus as claimed in any of claims 8 to 22 wherein means are provided for cooling the welding tips.

24. Apparatus as claimed in claim 23 wherein the cooling means include passages in the support.

25. Apparatus as claimed in any of claims 8 to 24 wherein the support is in the form of a plate.

26. Apparatus as claimed in claim 25 wherein the plate is mounted on an anvil.

27. Apparatus as claimed in any of claims 8 to 24 wherein the support is an anvil.

28. Apparatus as claimed in any of claims 8 to 27 wherein the welding tips are at least partly conical.

29. Apparatus as claimed in claim 28 wherein the welding tips are, at least in part, right circular cones.



30. Apparatus as claimed in claim 28 or 29 wherein the ratio of the height of the conical part of each welding tip to its maximum base dimension is approximately 1.2.

31. Apparatus as claimed in claim 28 wherein the welding tips are pyramids

32. Apparatus as claimed in any of claims 8 to 27 wherein the welding tips are at least partly of frusto-conical shape.

33. Apparatus as claimed in claim 32 wherein each welding tip is at least in part a portion of a right circular cone.

34. Apparatus as claimed in claim 32 or 33 wherein the ratio of the height of the frusto-conical part of each welding tip to its maximum base dimension is approximately 0.76.

35. Apparatus as claimed in claim 9 wherein each welding tip comprises a frusto conical portion on a cylindrical base whose diameter is larger than the base dimension of the frusto conical portion so as to provide the shoulder serving as a stop.

36. Apparatus as claimed in claim 35 wherein the ratio of the height of the frusto conical portion to its maximum base dimension is approximately 0.76.

37. Apparatus as claimed in claim 35 or 36 wherein the frusto conical portion is part of a right circular cone.

38. Apparatus as claimed in any of claims 8 to 37 wherein the means for supplying ultrasonic energy



comprises an ultrasonic horn extending along the weld line.

39. Apparatus as claimed in claim 38 wherein the ultrasonic horn is positioned on the side of the sheets remote from the welding tips.

40. Apparatus as claimed in claim 39 including means for moving the ultrasonic horn against the sheets so as to push the sheets against the welding tips to cause insertion of the welding tips into the sheets.

41. Apparatus as claimed in claim 40 including a stop for limiting movement of the ultrasonic horn once the welding tips have penetrated the sheets by the required degree.

42. Apparatus as claimed in any of claims 8 to 41 wherein the welding tips are arranged in a line, the tips adjacent the ends of the line extending further from the support than the tips in an intermediate part of the line.

43. A method of ultrasonically spot welding together a plurality of sheets of thermoplastic material, substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings; or as modified with reference to Figure 3 of the accompanying drawings; or as modified with reference to Figure 4 of the accompanying drawings.

44. Apparatus for ultrasonically spot welding together a plurality of sheets of thermoplastic material, substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings; or as modified with reference to Figure 3 of the accompanying drawings; or as modified



with reference to Figure 4 of the accompanying drawings.

45. A method of ultrasonically spot welding together a plurality of sheets of thermoplastic material, substantially as hereinbefore described with reference to Figures 5,6 and 7 of the accompanying drawings; or as modified with reference to Figure 8 of the accompanying drawings; or as modified with reference to Figure 9 of the accompanying drawings.

46. Apparatus for ultrasonically spot welding together a plurality of sheets of thermoplastic material substantially as hereinbefore described with reference to figures 5,6 and 7 of the accompanying drawings; or as modified with reference to Figure 8 of the accompanying drawings; or as modified with reference to Figure 9 of the accompanying drawings.

47. A system for spot welding a plurality of sheets of thermoplastic material together comprising:

(a) a plurality of welding tips adjacent to an obverse face of juxtaposed sheets of said thermo-plastic material, each of said welding tips extending from an anvil and having a base attached to said anvil and an apex spaced from said anvil at a predetermined height above said anvil, said plurality of welding tips extending along a weld line to be formed in said juxtaposed sheets;

(b) means for inserting said welding tips into an obverse face of said juxtaposed sheets a sufficient distance so that each welding tip at least partially penetrates each sheet of material being welded, said distance being less than the height of said apex of said each welding tip above the anvil from which said each welding tip extends, to thereby provide a reservoir space between said



anvil and the obverse face of said sheet material;
and

- 5 (c) means for applying ultrasonic energy
to said thermoplastic sheet material adjacent to
said welding tips whereby melted material may freely
flow into said reservoir space.

10 48. A method for ultrasonically spot welding together
a plurality of sheets of thermoplastic material along
a weld line, comprising the steps of positioning
a source of ultrasonic energy adjacent to a first
outer surface of the plurality of sheets, positioning
a support carrying a plurality of welding tips adjacent
to a second outer surface of the plurality of sheets
15 opposite said first outer surface and the source
of ultrasonic energy, inserting the welding tips
into the sheets along said line such that they at
least partially penetrate each sheet, there being
regions of the support adjacent the bases of the
welding tips which are spaced from said second outer
20 surface of the plurality of sheets, and supplying
ultrasonic energy from said source so as to weld
the sheets together.

25 49. A welding tip assembly for applying ultrasonic
energy to a plurality of juxtaposed sheets of thermoplastic
material to spot weld the sheets together comprising:
an anvil for supporting at least one frusto-
conical welding tip, the base of said welding tip
being supported by a major surface of said anvil
and having a maximum base dimension B parallel
30 to said major surface, the apex of said cone-shaped
tip being disposed at a height A above said major
surface, the ratio of A/B being approximately 0.76.



50. A welding tip assembly for applying ultrasonic energy to a plurality of juxtaposed sheets of thermo-plastic material to spot weld the sheets together comprising:

an anvil for supporting at least one cone-shaped welding tip, the base of said cone-shaped welding tip being supported on a major surface of said anvil and having a maximum base dimension B parallel to said major surface, the apex of said cone-shaped tip being disposed at a height A above said major surface, the ration of A/B being approximately 1.2.
